research review

OAR: The Research Agency
of The United States Air Force

VOLUME IV NUMBER 9 NOVEMBER 1965

PROTEIN MODELS

***COL HERMAN I. CHINN, Directorate of Life Sciences, AFOSR**

For decades, the complexity of protein molecules has fascinated and frustrated chemists around the world. In 1902, Emil Fischer received the Nobel Prize for his contributions to our knowledge of protein and amino-acid structure. Sixty years later, Kendrew and Perutz were similarly honored for their three-dimensional representation of certain simple protein molecules. In the intervening years, eight other chemists had received this ultimate scientific accolade for analyses of this enigmatic substance. Today, a virtual army of scientists is attacking the problem of protein structure with every tool at its disposal. Yet, none of the thousands of natural proteins have yet been synthesized, and the structures of only a few are known in detail.

The reason for this intense interest is readily apparent. Proteins are probably the most ubiquitous and versatile substances found in living matter. They are found in every cell, are involved in every biochemical reaction, and are vital to every biological process. They are present as enzymes, as hormones, as viruses, as structural components, as energy sources, as antibodies, and as genetic constituents. Knowledge of their intimate structures and the ability to synthesize or modify the molecules at will would have implications in every branch of medicine and agriculture.

Although the synthesis of natural proteins remains a tantalizing goal, considerable progress has been made in the preparation of models which possess many of the chemical and physiological properties of the native substances. At the turn of the century, Emil Fischer convincingly demonstrated that proteins are fundamentally amino-acid residues linked by peptide bonds. The number of these linked residues may range from a hundred or less to many thousands. Fischer and subsequent investigators succeeded in synthesizing low-molecular-weight peptides of definite constitution. These small molecules mimic some of the chemical properties of proteins. There remains, however, a tremendous gap between these simple synthetic models and the natural proteins whose molecular weights may exceed a million. The most intensive and successful attempts to bridge this gap have come from the laboratory of an AFOSR-supported investigator, Prof. Ephraim Katchalski at the Weizmann Institute of Science at Rehovoth,

**Col. Chinn was on active duty at AFOSR when he wrote this article.*

Israel. Katchalski and his colleagues have prepared a variety of amino-acid polymers with molecular weights ranging from one thousand to one million.

In several scores of publications, these scientists have contributed significantly to our knowledge of the physical and chemical properties of high-molecular-weight polymers. They have studied the polypeptide backbone and the effect of different side chains on the conformation and stability of the molecule. They have probed the chemical reactivity of these side chains and their interactions with neighboring groups. Most importantly, they have used the synthetic models to explore the varied biological properties of proteins. Some of the polymers have served as excellent substrates for enzyme activity. Others have interacted with viruses and bacteria. Still others have served as antigens to elicit antibody response in animals. Certain of the compounds have shown promise as blood-plasma substitutes. A few have demonstrated significant activity against certain fungi. Some have affected the normal blood-clotting processes.

Despite the prolific flow of reports from his laboratory, Katchalski has merely erected signposts to indicate the versatility of this approach. Each of the pathways he has pointed out will unquestioningly become well-travelled avenues of research where significant extension of our knowledge in basic processes can be confidently predicted. As our understanding increases, important applications to medicine seem inevitable. ★

research review
OFFICE OF AEROSPACE RESEARCH

OAR RESEARCH REVIEW is published monthly by the Office of Scientific and Technical Information (RRYC), Hq Office of Aerospace Research, USAF, 4th and Independence Avenue, S.W., Washington, D.C. 20333. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities.

JACOB SEIDEN
Editor

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measuring diffusion in SOLIDS

CAPT K.J. RICHARDS, Metallurgy and Ceramics Research Laboratory, ARL

Diffusion is an important factor which affects many properties of solids. It is, in fact, the fundamental rate process in the solid state. Diffusion, for example, is important in sintering, solid-state reactions, and many oxidation processes. High-temperature creep deformation and other mechanical rate processes may also be controlled by ion mobilities. In addition, diffusion plays an important role in the field of solid-state electronics. As a consequence, a considerable amount of attention has been given, in recent years, to experimental and theoretical studies of the mechanisms of mass transport in solids.

One of the experimental techniques that has been widely used to measure diffusion coefficients in solids is the decrease in the surface-activity method. Experimentally, a vanishingly thin deposit of radioactive tracer is made on a flat surface of a semi-infinite specimen. The decrease in the intensity of the radiation from this "active" face, due to the diffusion of the tracer into the specimen, is then measured by counting the "active" surface before and after a diffusion anneal. Under these experimental conditions, the appropriate solution to the diffusion equation for the distribution of radioactivity in the specimen after a diffusion anneal is

$$C = \frac{Q}{\sqrt{\pi Dt}} \exp(-x^2/4Dt) \qquad (1)$$

where C is the concentration of tracer at a depth x from the initial radioactive deposit, Q is the number of tracer atoms per unit area initially deposited, and D and t are, respectively, the diffusion coefficient and the diffusion time.

Due to the absorption of radiation by the specimen, the activity measured at the "active" surface decreases as the tracer diffuses into the solid. Thus, if the absorption of radiation from the radioactivity contained in an infinitesimally thin layer of material a distance x from the surface follows Lambert's Law, the incremental contribution of this tracer to the total measured activity, A, is

$$dA = \kappa C \exp(-\mu x)\, dx \qquad (2)$$

κ is a constant to correct for counting efficiency, units, etc., and μ is the linear absorption coefficient for the tracer radiation in the diffusion specimen. By combining equations (1) and (2) and integrating over the sample thickness (effectively from zero to infinity), the following solution given by Steigman, Shockley and Nix is obtained:

$$A = \kappa Q \,\mathrm{eerfc}\,(\mu^2 D t)^{\frac{1}{2}} \qquad (3)$$

where $\mathrm{eerfc}\,(y) \equiv \exp(y^2)\,[1-\mathrm{erf}\,(y)]$ and erf (y) is the Gaussian error integral. From equation (3), it can be seen that κQ is equal to the initial surface activity, A_0. Therefore, the ratio of surface activity after and before a diffusion anneal is

$$A/A_0 = \mathrm{eerfc}\,(\mu^2 D t)^{\frac{1}{2}} \qquad (4)$$

An important experimental convenience of the decrease in the surface-activity method which is implicit in equation (4), but which does not seem to have been generally recognized or applied, has its origin in the fact that a unique value of the activity ratio is determined for a particular product of D and t. In other words, Dt is the true diffusion parameter. Suppose that a diffusion anneal is made at temperature, T_1, for time, t_1. The activity ratio would be given by

$$(A/A_0)_{D_1 t_1} = \mathrm{eerfc}\,(\mu^2 D_1 t_1)^{\frac{1}{2}} \qquad (5)$$

If the same sample is now run for an additional time, t_2, at a new temperature, T_2, the ratio becomes

$$(A/A_0)_{D_1 t_1 + D_2 t_2} = \mathrm{eerfc}\,(\mu^2 D_1 t_1 + \mu^2 D_2 t_2)^{\frac{1}{2}} \qquad (6)$$

The result of the anneal at T_1 is equivalent to a run at T_2 for a time τ where

$$D_1 t_1 = D_2 \tau \tag{7}$$

Thus, substituting equation (7) in equation (6) gives

$$(A/A_o)_{D_1 t_1 + D_2 t_2} = \text{eerfc}\,(\mu^2 D_2 \tau + \mu^2 D_2 t_2)^{\frac{1}{2}} \tag{8}$$

It may be shown that equation (8) can be generalized, and that a single value of τ can be chosen to represent the entire previous thermal history of a sample. It follows that the activity ratio of a specimen prior to an anneal at a temperature, T, for which the diffusion coefficient is D may be written as

$$(A/A_o)_{D\tau} = \text{eerfc}\,(\mu^2 D\tau)^{\frac{1}{2}} \tag{9}$$

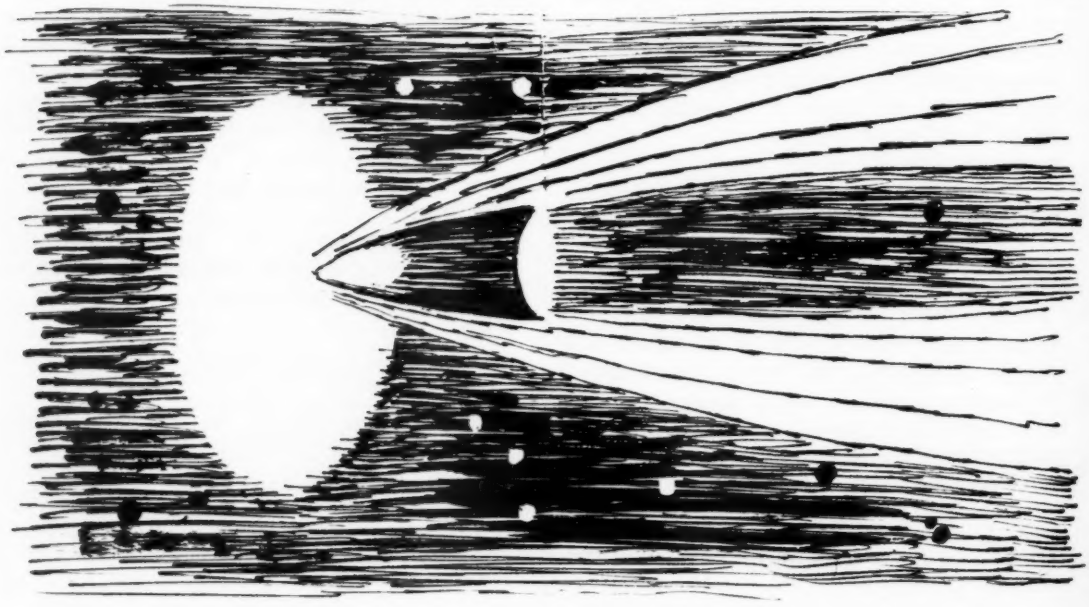
and the ratio after an anneal of duration, t, at this temperature may be written as

$$(A/A_o)_{D\tau + Dt} = \text{eerfc}\,(\mu^2 D\tau + \mu^2 Dt)^{\frac{1}{2}} \tag{10}$$

The diffusion coefficient, D, may now be evaluated by first determining, from a tabulation of the "eerfc" function, the values of $\sqrt{\mu^2 D t}$ that correspond to the measured activity ratios. Thus,

$$D = \left\{ \left[\text{eerfc}^{-1} (A/A_o)_{D\tau + Dt} \right]^2 - \left[\text{eerfc}^{-1} (A/A_o)_{D\tau} \right]^2 \right\} (\mu^2 t)^{-1} \tag{11}$$

This analysis indicates that the decrease in the surface-activity method offers the convenience of being able to use a single sample for multiple diffusion measurements. Under certain conditions, this can be of considerable experimental value, for example, when the sample material or radioactive tracer is scarce, or when it is expedient to obtain results quickly with limited experimental facilities. In the Metallurgy and Ceramics Research Laboratory at ARL, this technique is being successfully applied in several studies of self-diffusion and impurity diffusion in refractory metal oxides with the result that accurate, meaningful data have been obtained with very significant savings in time and money. (This research is funded wholly/in-part by the Air Force In-House Laboratory Independent Research Fund.) ★



Perchlorocarbons: the odyssey of a modern Spanish explorer

DR. LEONARD SPIALTER, Chemistry Research Laboratory, ARL

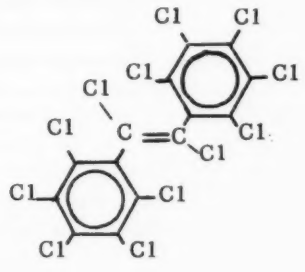
The philosophy of picking a simply defined, large, unexplored and nonpopular class of molecules with millions of potential members and performing good fundamental chemical research thereon has frequently proven to be a profitable, though not too often diligently followed, path leading to the discovery of unexpected phenomena and useful practical substances. Another recent case in support of this concept is exemplified by the research pioneered in alkylaryl perchlorocarbons by Dr. Manuel Ballester, Professor of Chemistry at the University of Barcelona, Spain, and Researcher in the Patronato "Juan de la Cierva" of the Consejo Superior de Investigaciones Científicas (The Spanish Higher Council for Scientific Studies).

Dr. Ballester, whose only outside support has come from contracts with ARL, has concerned himself with molecular architecture constructed solely from atoms of carbon and chlorine. To these compounds he has given the name perchlorocarbons. In principle, to every hydrocarbon (molecules based on hydrogen and carbon, such as ethane, toluene, polystyrene, etc.) there corresponds a perchlorocarbon of the same structure and configuration. Consequently, the perchlorocarbons can be alkyl, aromatic, or alkaromatic.

The difficulties encountered in the synthesis of members of the perchlorocarbon class have been so great in the past that previous examples of such compounds have been limited to a few (about 10) well-known substances, including carbon tetrachloride, tetrachloroethylene, hexachlorobenzene, and hexachlorobutadiene. Problems have been caused mainly by two factors: atomic overcrowding (steric or space hindrance), and electronic effects. These normally build up as the number of chlorine atoms introduced in place of hydrogen increases, and reach a maximum in the perchloro configuration for a given carbon skeleton in the molecule. The handicaps are not as great in the closely related and well-studied (since World War II) perfluorocarbons where similar electronic factors are important, but not the steric requirements, because fluorine atoms, unlike chlorine, are small and about the same size as hydrogen.

One of the vexing problems in the past has been that of finding a suitable chlorinating reagent which will replace all of the hydrogen atoms in a hydrocarbon by chlorine. The known reagents were either too weak to replace all of the hydrogen, or so powerful that the molecule undergoing substitution was broken down into smaller fragments. Prof. Ballester has discovered that a properly heated mixture of sulfuryl chloride (SO_2Cl_2), sulfur monochloride (S_2Cl_2), and aluminum chloride (Al_2Cl_6) proved to be the proper reagent. It is exceedingly powerful in replacing hydrogen by chlorine, but so balanced and selective in its behavior that fragmentation does not generally occur. The availability of this unusual perchlorinating agent has allowed the preparation of a considerable number of new chlorocarbons, some of them with remarkable properties, and also the discovery of important phenomena, reactions and correlations.

Among the more than 50 new perchlorocarbons synthesized by Dr. Ballester and his group at Barcelona, several have been found with extraordinary behavior. For example, several are stable in air at temperatures of 500°C (red heat). Some have been boiled for hundreds of hours with fuming nitric acid with no decomposition. One such typical molecule is trans-perchlorostilbene:



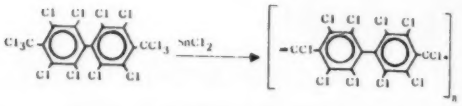
In other perchlorocarbons, reactive chloroalkyl substituents, such as trichloromethyl groups (Cl_3C-), are routinely converted to carboxyl groups (HO_2C-) by treatment with fuming sulfuric acid:

Ordinarily, double bonds (-C=C) and benzene rings react vigorously under these conditions with destruction of the molecule, but the perchloroanalogs remain untouched except for the desired conversion.

These same trichloromethyl groups ($-CCl_3$) have been found to participate in another unique and useful reaction. Under the influence of stannous chloride or the iodide ion, two such groups lose four chlorine atoms and join together:

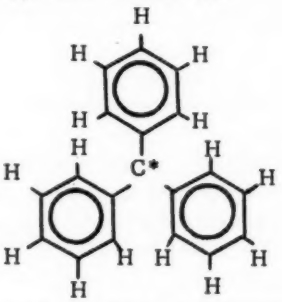
$$2RCCl_3 \xrightarrow[\text{or } Sn^{++}]{I^-} R\text{-}\overset{Cl}{\underset{|}{C}} = \overset{Cl}{\underset{|}{C}}\text{-}R$$

where R is a perchlorocarbon group. If a perchlorocarbon molecule contains two such groups, the above reaction can be propagated in two directions, giving rise to a polymer. Indeed, Dr. Ballester has been able to prepare polymers by this means with molecular weights greater than 30,000. For example, the reaction of perchlorobi-p-tolyl with stannous chloride gives about 75% yield of a well-characterized macromolecular chlorocarbon with the molecular weights of different fractions varying from 5,000 to 27,000:



Such polymers have excellent thermal stability above 400°C and are readily handled substances. Useful plastics and fibers could well be developed from such reactions and products.

The large space-filling nature of chlorine atoms, in addition to introducing bond distortions into the perchlorocarbons, has also provided steric hindrance (blocking) to chemical reactions. For example, it has long been known that the molecular fragment, triphenylmethyl free radical (I),

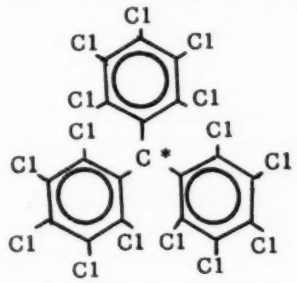
I 

can exist although the odd electron (indicated by the dot on the central carbon) is so reactive that the fragment reacts vigorously with all kinds of molecules, including oxygen, chlorine, nitric oxide, bromine and free radicals, including itself. However, Prof.

Scale molecular model of perchlorotriphenylmethyl free radical. Note: The three chlorine atoms, labelled Cl, prevent access to electron site (central white spot).

Ballester has found that his perchloroanalog (II),

II



as a result of the space-filling and shielding effect of the six chlorine atoms (nearest the normally reactive odd electron) which prevents the approach of any other atom or molecule, is so inert that the radical (II) does not react with any of the common molecules mentioned above. It is the first carbon free radical which appears to have complete stability, in the crystal form or in solution, in prolonged contact with air. This useful property has recommended it as a standard for paramagnetic resonance studies. Preliminary physical measurements have been very promising and this, as well as related compounds, should find useful application in magnetic field and frequency-measuring devices.

For his pioneering achievements in perchlorocarbon chemistry, all achieved under ARL contractual support, and his delineation of the path to new phenomena and potential products therefrom, several honors have been bestowed on Prof. Ballester during the past six months. The Spanish government has appointed him "Knight-Commander of the Order of Alfonso X, The Wise." He has received the "Centenaire de la Société Chimique de France" medal, and has been invited by the International Union of Pure and Applied Chemistry to deliver a plenary lecture before the International Symposium in August 1966 commemorating the 100th anniversary of the birth of Moses Gomberg, the discoverer of organic free radicals. Numerous other invitations to lecture, and other honors, have been profferred.

A number of chemical companies have shown interest in the results of Prof. Ballester's fundamental research program, and a many-pronged approach to exploitation of the chlorocarbons is now in progress. ★

REFERENCES

Ballester, M., A Study of the Synthesis and Properties of Alkaromatic Chlorocarbons, Aerospace Research Laboratories' Technical Report ARL 64-141, Sept. 1964.

Ballester, M. and J. Riera, "Perchlorodiphenylmethyl (PDM), a Carbon Free Radical of Remarkable Stability," Journal of the American Chemical Society, 86, 4505, 1964.

Ballester, M., C. Molinet and J. Rosa, "The 'Positive Halogen' Reaction between Benzotrichlorides and Potassium Iodide," Tetrahedron, 6, 109, 1959.

twenty-two year magnetic cycle

SPACE PHYSICS LABORATORY, AFCRL

A 22-year solar magnetic cycle is associated with the 11-year sunspot cycle. Changes in the magnetic polarity of sunspots from one 11-year period to the next were noted as long ago as 1913. The effects of this 22-year magnetic cycle on geomagnetic activity on the earth have not been analyzed until recently.

These effects are pointed up in a recent study by Edwin J. Chernosky of AFCRL. In his study, Chernosky analyzed daily geomagnetic data for an 80-year period (29,219 days) from 1884 through 1963. He found that the earth's geomagnetic activity in one 11-year sunspot cycle period had a distinctly different pattern from the geomagnetic activity in the following sunspot cycle.

One implication of Chernosky's study is that solar astronomers and environmental scientists cannot assume that IGY data collected in the late 1950's, and IQSY data collected during the past 18 months, will provide a valid basis for extrapolation of all environmental events during the next solar sunspot cycle. They may have to evaluate data from another 11-year cycle before such extrapolation is possible.

The causes of the 22-year variation in geomagnetic data on the earth are related to the reversal in the magnetic polarities of

sunspot pairs from one 11-year cycle to the next. The causes of this reversal, and why it should influence the earth's geomagnetic field, are not understood. What is meant by a reversal of magnetic polarities of sunspot pairs? A sunspot can be considered as an optical indication on the solar surface (the photosphere) where a concentration of lines of magnetic force enters or leaves the surface. Bipolar sunspot pairs usually have their joining axis in an east-west direction. We find that, during one 11-year cycle, the magnetic lines leave (north polarity) the east sunspot while, in the next cycle, the lines enter (south polarity) the east sunspot.

We tend to think of the 11-year sunspot cycle as a rigid, unvarying time cycle. Actually, the cycle has averaged about 11-1/3 years since 1750--but the 6 cycles between 1901 and 1964 have averaged less than 11 years in spite of the fact that one lasted 12 years. The cyclic nature of sunspot activity was discovered in the mid-1800's. All sunspot cycles recorded before and after this discovery have been identified by number. The solar cycle just being completed, for example, is number 19.

In his study, Chernosky compared geomagnetic disturbances that occurred during even-numbered cycles with disturbances during odd-numbered cycles. Based on daily recordings of geomagnetic activity since 1884, Chernosky found that, for even-numbered sunspot cycles, geomagnetic disturbances are less severe during the first half of the cycle than during the second half. For odd-numbered cycles, the reverse is true.

Twenty-two year changes in the annual variation of magnetic activity were also evidenced. At and after one sunspot minimum, the biannual maxima at the equinoxes are quite clear and pronounced. At the alternate sunspot minimum, the peaks at the equinoxes are poorly defined. In March and September of each year, a condition exists which should favor increased terrestrial magnetic activity. At these times, the earth is at a high heliographic latitude which locates the earth favorably with respect to direct radiation from the sunspot zones. The sunspot zones are on each side of the solar equator, and extend from a few degrees from the equator to middle latitudes.

Also, in March and September the sun passes over the earth's equator. Whether this symmetrical positioning of the sun with respect to the earth is important to the production of terrestrial magnetic activity, is not known. ★

COOPERATIVE RESEARCH- AT MACH 20

ROBERT J. SHANAHAN, Fluid Dynamics Facilities Laboratory, ARL

Current in the inventory of Air Force concerns is the dynamic stability characteristics of re-entry-type configurations at high hypersonic Mach numbers. In the effort directed toward solution of this urgent problem, the experimentalist has been in the foreground, since no adequate analytical model has been set forth from which a concerted theoretical effort might proceed.

In the search for explanations or logical interpretations of flight behavior, and for reason of providing a larger experimental base upon which to build a sound analytical model, the experimental program has made use of various types of ground testing facilities. One such type, the short-duration hotshot facility, has been employed by personnel of the Arnold Engineering Development Center (AEDC) for the determination of aerodynamic damping derivatives at nominal Mach numbers near 20. Since the hotshot facilities operate with useful run times on the order of 50 milliseconds, the acquisition of dynamic data is somewhat restricted. In dynamic stability testing, a large number of sample cycles are desirable since they allow more accurate evaluation of the data from which the damping derivatives are obtained. The oscillation frequencies of models tested in short-duration facilities, then, must be high (150 cps) to obtain even a minimum number of sample cycles. With the high oscillation frequency, the reduced frequency of the dynamic model becomes much higher than the reduced frequency of the flight article. In order to relate the test data to the flight

article, the effect of reduced frequency must be determined by comparing the hotshot results with results obtained in long-duration hypersonic facilities where full-scale reduced frequencies may be duplicated.

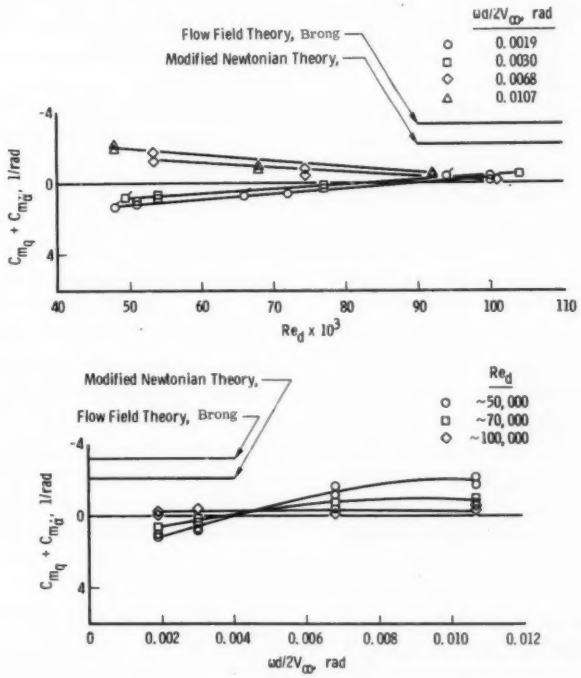
In consideration of the above, a cooperative testing program was planned and conducted by personnel of AEDC and ARL. A standard 10-degree half-angle cone was tested in the ARL 30-inch hypersonic wind tunnel utilizing an AEDC model and balance system. The ARL 30-inch hypersonic wind tunnel operates with useful run times on the order of 2 minutes, at Mach numbers between 16 and 22, and with Reynolds numbers comparable to those of the AEDC hotshot facilities. The AEDC balance is a remotely controlled, pneumatically operated, low-amplitude ($\pm$2 degree) one-degree-of-freedom system utilizing a gaged cross flexure as the pivot.

Damping in pitch derivatives ($C_{m_q} + C_{m_\alpha}$) was determined at a nominal Mach number of 20 over a reduced frequency range ($\omega d/2V_\infty$) of 0.0019 rad to 0.0107 rad with Reynolds numbers (Re_d based on maximum model diameter) varying between 50,000 and 100,000.

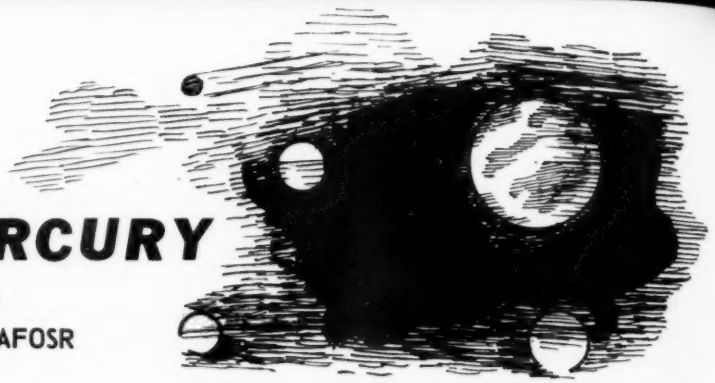
The results appeared to be consistent with the data obtained in the AEDC hotshot facility at higher reduced frequencies (0.030 rad). Increasing the frequency of oscillation was shown to increase the dynamic stability at the low Reynolds numbers, but to not significantly affect it at high Reynolds numbers. Further, it was shown that increasing the Reynolds number may dynamically stabilize or destabilize a model, depending on the oscillation frequency.

The work covered in this article was published jointly by R. H. Urban, ARO, Inc., and R. J. Shanahan, ARL, in the report, "Dynamic Stability Characteristics of a 10-Degree Cone at Mach Number 20," AEDC-TR-65-80, April 1965.

Subsequent data obtained at AEDC at a nominal Mach number of 10 in a continuous facility substantiate the reduced frequency, Reynolds numbers trends established at ARL. Further investigations are proceeding in these areas. ★



ROTATION OF THE PLANET MERCURY



DR. MARSHALL C. HARRINGTON
Directorate of Physical Sciences, AFOSR

At the Spring 1965 meeting of the American Geophysical Society held in Washington, Gordon H. Pettingill and Rolf B. Dyce of Cornell University reported new information concerning the rotation of the planet, Mercury, which for many years had been supposed to rotate, as does the moon, so as to present the same face to its primary. Thus, Mercury's "day" was thought to be equal to its "year," that is, 88 Earth days. Now it is found that its sidereal period is 59 $\pm$ 5 days. This discovery is due to a continuing study of the planets as observed by the powerful radar of the Arecibo Ionospheric Observatory in Puerto Rico. The Observatory is operated by Cornell University under the sponsorship of the Advanced Research Projects Agency, and is monitored by the Air Force Office of Scientific Research. The instrument employed consists of a stationary reflector of wire mesh forming an inverted spherical cap 1000 feet in diameter. The radar signal at 430 Megacycles per second has a peak power of 2 Megawatts. The radar feed is movable within a cone of 20 degrees semi-angle with a vertical axis. The site, at a low latitude (18^{O} N), had been chosen so that the planets are accessible in a nearly vertical direction.

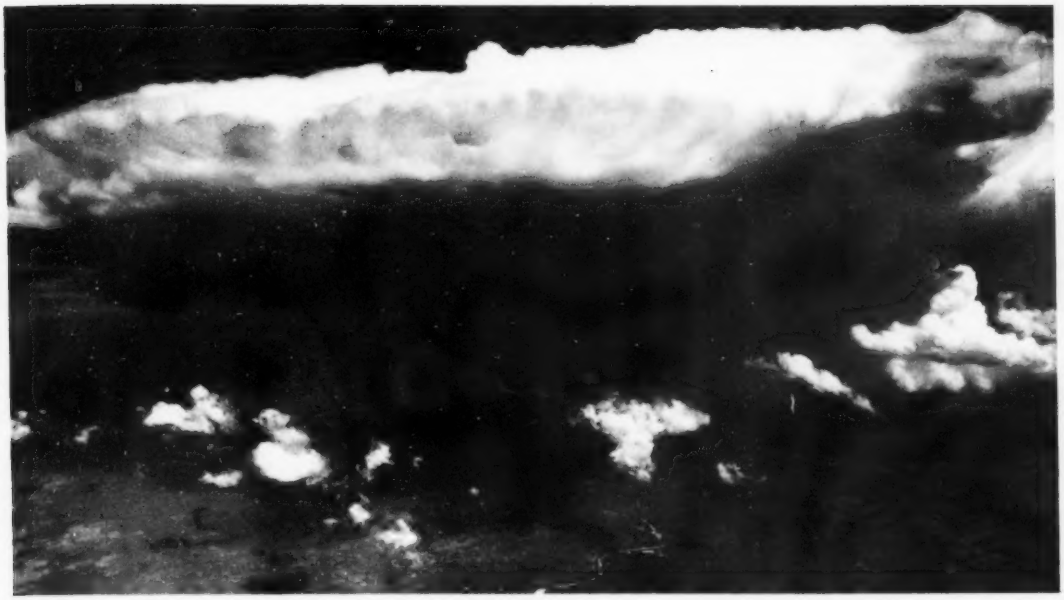
Mercury was observed near its inferior conjunction in April of this year. Analysis of radar signals reflected from the planet permitted the new determination of the period of its rotation. This is possible because the reflection from a rotating object contains a band of frequencies on either side of the central frequency, as determined by the Doppler effect. This is the effect so often noticed when the frequency of the horn of a passing automobile is altered as the car goes by the listener. The same effect applies to radio waves reflected from a moving object. Thus, the frequency of that part of the signal reflected from the portion of the planet which is rotating toward the Earth is increased above the center frequency, and that from the portion which is rotating away from the Earth is correspondingly diminished. Consequently, by measuring the spread in the frequency of the return signal, it is possible to determine the rate of rotation.

The direction of rotation was found to be the same as that of the Earth, namely, in the direction of revolution about the Sun. Since the period of revolution of Mercury about the Sun is 88 days, the interval between one sunrise on the planet and the next is thus about 180 Earth days. The data so far obtained are not sufficiently precise to determine the orientation of the axis of rotation, but they are consistent with the previous view that the axis is nearly perpendicular to the plane of the planet's orbit around the Sun.

The radar reflectivity of Mercury was found to be similar to that of the Moon, namely, 0.06 of that of a perfectly reflecting target of the same size. Also, it was inferred that Mercury and the Moon have about the same degree of average roughness on the scale of the radar wave length (70 cm in this case).

These results and those previously reported on Venus* illustrate the power of the Arecibo instrument in obtaining new information about the Earth's nearest neighbors. Radar observations of these objects are being continued at Arecibo. Further refinements in these findings and additional information about the Moon and other planets may be expected. ★

*OAR RESEARCH REVIEW, Vol. III, No. 3, page 20, May 1964.



Air Flow in Severe Thunderstorms. The internal dynamics of large thunderheads are exceedingly complex. This photograph of a thunderhead was made by AFCRL scientists in Oklahoma, and is of the type treated by Dr. Keith A. Browning in his study.

air flow in severe thunderstorms

METEOROLOGY LABORATORY, AFCRL

Thunderstorms that occur on hot summer afternoons in the mid-latitudes are complex energy systems. Radars have probed them, meteorological aircraft have flown through them, and precipitation samples--rain and hail--have been collected within them--but the pattern of air flow and precipitation is seen, at best, only in dim outline.

One familiar outline is the generalized diagram of air flow within these giant systems seen in textbooks. In this diagram, we see vertical arrows depicting the warm updrafts on the side of the storm's forward motion, and downward pointing arrows of cold downdrafts and precipitation on the storm's opposite side. This model is all right as far as it goes--but thunderstorm dynamics have a much richer pattern. Moreover, there are different kinds of thunderstorms. The most damaging variety of storms--the kind that produces both hail and tornadoes--commonly travels to the right of the general wind flow in the Northern Hemisphere. Such a storm is called an SR storm (S for severe, and R for right); in the Southern Hemisphere, the same kind of storm would be classed SL.

A model for the air-flow and precipitation patterns in SR thunderstorms has recently been proposed by Dr. Keith A. Browning of AFCRL. This model unifies a number of previously known characteristics of severe local storms.

In Browning's model we see that the air flow associated with a particular thunderstorm, typically rising 10 km in altitude, may extend over an area of 100 km near the ground level. The warm updrafts originating near the ground sweep upward in a well-defined stream that describes a spiral of about 270 degrees, and terminates in the familiar anvil top of the thunderhead. The cold downdraft, originating at the midlevel of the cloud and driven by the evaporation of precipitation, also describes a spiral, but in the opposite direction.

The interesting feature of Dr. Browning's air-flow model is that the downdraft flow circles around the stream of upward flowing air. It loops over the top of the updraft stream at one point and under it at another. A drawing of this updraft-downdraft pattern looks somewhat like the familiar Chinese puzzle of two interlocking nails.

If we look down on the thunderhead from above, we see that the precipitation pattern somewhat resembles the spiral arms of a stellar galaxy, with the precipitation spiraling outward from the center of the storm. The symmetry of the pattern is somewhat askew, with most of the precipitation reaching the ground on the storm's left flank.

Looking at a two-dimensional vertical profile of the storm, we see that the warm updraft originates in a roughly horizontal flow near the ground and terminates (with the wind flow in the opposite direction) in the horizontal cloud anvil--a U-shaped configuration--with the open end of the U in the direction of the storm's movement. Precipitation flows out along the top bar of this horizontal U--the cloud anvil. When it falls, it must pass through the updraft stream at a lower level. It is captured by these updraft winds and is recycled. Thus, the precipitation particles caught in this recycling process describe a circular motion. As these particles rise back up through the center of the storm, however, a kind of fountain effect exists, with part of the particles moving in one direction to be caught again and recycled, and part moving toward the trailing side of the storm. Those moving toward the trailing side are not recaptured. They reach the ground as hail or rain within a limited area under the much larger thunderhead. Typically, this area of precipitation extends about 10 km. ★

BACK-PACK ON THE MOON

MAJOR BERNARD S. MORGAN, JR., Aerospace Mechanics Division, FJSRL

The problem of traveling from one point to another on a flat earth has long been a practical consideration for man. With the prospect of manned exploration of planets and satellites having little or no atmosphere to impede or disturb flight, the use of rocket propulsion becomes a very attractive and practical means of moving men and equipment over unprepared terrain. As the aerospace mission of the Air Force develops, it will be necessary to understand the advantages offered by the several means of locomotion, and to have quantitative information upon which to base a choice.

Major O.J. Manci, a member of the Frank J. Seiler Research Laboratory, Aerospace Mechanics Division, is concerned with research on the application of mathematical optimization techniques. Specifically, he has considered the problem of flight over the moon, without any atmosphere. In technical report SRL 64-3, he presents minimum fuel trajectories with soft landings for travel through negligible atmosphere over distances such that the gravity field can be considered uniform, e.g., ranges of 30 miles and altitudes of 5 miles on the moon. (1)

The solution to the problem is subject to the differential constraints of the equations of motion and the end point conditions which require zero velocity at take-off and soft landings. This system of equations involving five parameters is reduced to a two-parameter system by means of dimensional analysis. Pontryagin's maximum principle is employed to reduce the problem to a two-point boundary-value problem with the optimality condition included. The resultant formulation requires the determination of four undetermined multipliers.

Such two-point boundary-value problems are most frequently solved on digital computers. The unique feature of the report is the use of an analog computer to solve the problem. Solutions are presented as: (1)

curves of the initial condition of each Lagrange multiplier; (2) rocket cutoff and reignition times; (3) total flight time; (4) initial thrust angle; and (5) final mass fraction, all as functions of range. The initial mass is the parameter in each of these families of curves.

A method for mechanizing this solution suitable for one-man "back-pack" type as well as heavier systems is described. This open-loop control system requires only a simple stable platform and cam follower driven by a constant-speed motor to achieve the desired trajectories. ★

REFERENCE

(1) Manci, Jr., Major Orlando J., Minimum Fuel Trajectories with Soft Landings, SRL 64-3, Frank J. Seiler Research Laboratory.

DOES CYANIDE REALLY GIVE MORE TIME FOR RELAXATION? (The Effect of the Cyanide Ion on Relaxation Time)

DR. AMOS G. HORNEY
Directorate of Chemical Sciences, AFOSR

Because of the tendency toward a shorter work week, there are many among us who have a great interest in "relaxation time." In this category must be placed Professor V. Gold of Kings College, London, who has found while working on an AFOSR Directorate of Chemical Sciences contract that the cyanide ion has a great effect on the relaxation time of the nickel ion. The nickel ion is not the sort of creature that one usually thinks of in terms of leisure. Nor, in fact, is cyanide usually associated with relaxation (except perhaps for certain unhappy spouses who think in terms of "Divorce--Chemical Style"). The "relaxation time" measured by Professor Gold is a measure of the rate of certain reactions occurring in solution. When a system at equilibrium is subject to a very rapid change of conditions, there is a finite time required for a new equilibrium state to be attained. The "relaxation time" of a system is a numerical measure of the time necessary for the new equilibrium state to be reached.

The process involved in Professor Gold's measurements is the alignment of the magnetic movements of hydrogen nuclei with an external magnetic field--(Nuclear Magnetic Resonance). And the relaxation is involved with movement of the water molecules containing these atoms, in the vicinity of the nickel ion. If a molecule remains near the metal ion for a long time, it has a long "relaxation time"; otherwise, it has a short one.

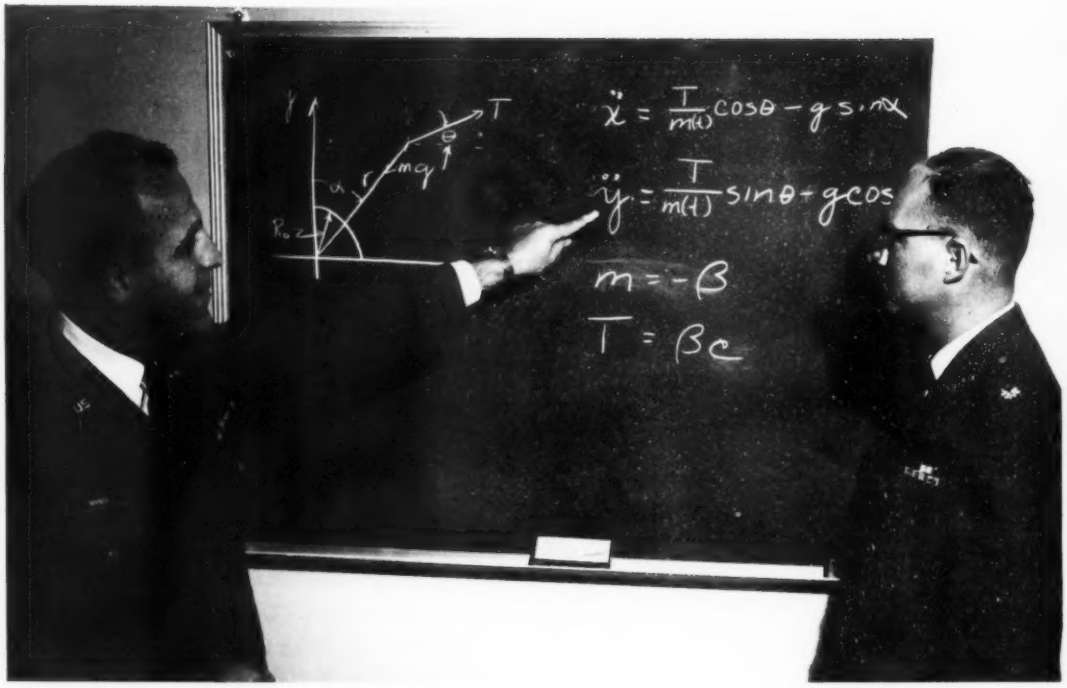
One of the aims of this study was to ascertain how the relaxation times of protons associated with complex species are affected by solvent or medium effects. For instance, it was found that the cyanide ion in solution causes a dramatic effect on the relaxation time of H_2O protons which are associated with paramagnetic Ni(II). This effect, it was shown, can be quantitatively correlated with the formation of diamagnetic $Ni(CN)_4^{-2}$ ion.

Previous studies which had postulated paramagnetic species such as $Ni(CN)_6^{-4}$ were shown to be in error, in all probability due to inhomogeneities in the magnetic field used.

A different type of medium effect was noted in studies of organic substances. Here the chemical process which was involved was the addition of H_2O to the molecular species. For instance, pyruvic acid and acetaldehyde were observed to undergo hydration at measurable rates. The use of the NMR technique facilitates study of otherwise inaccessible systems, but the relaxation involved is not synonymous with leisure.

Fundamental new information on the behavior of matter under rapidly changing conditions, such as that revealed by the above research, is needed continually in the unending quest by the Air Force for novel materials with superior properties. ★

PROFILES



Major Orlando J. Manci, Jr., is shown briefing Major Bernard S. Morgan, Jr., on the Back-Pack problem at the Frank J. Seiler Research Laboratory. Major Morgan recently relieved Major Manci as Director, Aerospace Mechanics Division, FJSRL. The Aerospace Mechanics Division conducts basic research in aerospace mechanics with emphasis on gas dynamics, control theory and hybrid computation. It also provides facilities and assistance for the students and faculty of the United States Air Force Academy. Major Manci, the first director of the Aerospace Mechanics Division, is now head of the Department of Aeronautics, USAF Academy. Prior to his assignment to FJSRL, he was chief of the Aeromechanics Division, European Office of Aerospace Research, OAR. He holds a bachelor's degree from the US Naval Academy (1950), two master's degrees, one in Aeronautical and another in Instrumentation Engineering (1957), and a Ph.D. (1960) in Instrumentation Engineering, all from the University of Michigan. A portion of his research is reported by Major Morgan in this issue of the Review in the article, "Back-Pack on the Moon." Major Morgan was a frequent contributor to the Review while a member of the General Physics Division, and then Applied Mathematics Division, AFOSR. Prior to his present assignment, he was a student at the Armed Forces Staff College, Norfolk, Virginia. Major Morgan holds a bachelor's degree from the US Naval Academy (1951), two master's degrees, one in Aeronautical Engineering and another in Instrumentation (1957), and a Ph.D. (1963) in Instrumentation Engineering, all from the University of Michigan. Major Morgan, whose research interest is in control theory, recently presented an invited address on multivariable systems at the 1965 IEEE International Convention. He received a citation as outstanding scientist in the Washington, D.C. area from the Washington Academy of Scientists in 1962.

Captain Adelbert McIntyre attended Indiana University and is a graduate of the University of Rhode Island. At present, he is pursuing graduate studies in physics at Northeastern University. At the University of Rhode Island, he became a member of the faculty in the Department of Physics, and concurrently pursued research into the infrared spectra of selected liquids for the United States Navy. He left the University of Rhode Island to become a member of the Advanced Studies Group of the Naval Underwater Ordnance Laboratories where he continued to perform research in fundamental physical phenomena. In 1961, Capt. McIntyre was recalled to active duty and was subsequently assigned to the Office of Aerospace Research, where he was responsible for managing the selection of scientific experiments for the Air Force rocket and satellite research program. In September 1963 he was assigned to AFCRL to manage the rocket and satellite program, and subsequently assumed duties as a program area coordinator in aeronomy and astrophysics. Capt. McIntyre's article, "AFCRL Rocket Program: Historical Perspective," appeared in the Sept. 1965 Review.

Mr. Robert J. Shanahan, ARL scientist, is currently conducting gasdynamics investigations to: (a) determine the temperature distribution in a blunt-body shock layer in hypersonic flow (part of a program of measurement of high temperatures in wind tunnels utilizing an infrared, monochromatic radiation pyrometer); (b) develop the equations for the computation of isentropic flow tables for high-enthalpy air (dissociation effects included); and (c) analyze 30-inch HWT component effectiveness using experimental data as the prime input. Mr. Shanahan received his M.S. degree (Aeronautical Engineering) from the University of Illinois in 1961. Since 1962, he has been assigned as an aerospace research engineer, Fluid Dynamics Facilities Laboratory, ARL. He has several publications to his credit. In this issue of the Review, Mr. Shanahan discusses "Cooperative Research - at Mach 20."

Surface Studies & the Mössbauer Effect

MAX SWERDLOW, Directorate of Physical Sciences, AFOSR

There is more unknown than is known about the role and behavior of surfaces and interfaces. In spite of this lack of knowledge and understanding, the importance and variety of surface phenomena are great. Processes occurring at surfaces are significant in many areas of physics, chemistry, and biology. Diffusion from one medium into another must go through a surface. Catalysis occurs predominantly at surfaces. Many other effects involving surfaces will occur to anyone after some thinking. It is therefore no surprise that studies of the chemical and physical processes at surfaces have a long history. However, the vast majority of all experiments done before 1950 must be classed as "studies of dirty surfaces" and, unfortunately, even many investigations performed today belong to the same category. The reasons are not difficult to find: surfaces are hard to prepare in a clean and well-defined way; they are hard to keep clean; and they are hard to study! Consider first the preparation of a clean surface. How shall it be done? Take an existing surface of, say, a metal. Chances are that it will not look like the "plains" of Illinois, but more likely will have the structure of the wild country around the Grand Canyon. Instead of studying the properties of the surface, we could end up investigating properties of cracks, faults, outcroppings, steps and the like. The best hope to approximate an ideal surface lies in the use of a single-crystal plane carefully cleaned and protected from damage.

Assume, then, that we have succeeded in preparing a clean surface. Obviously, we cannot keep it in a normal atmosphere--it would be contaminated much too quickly. We will therefore prepare and clean the surface in a vacuum. Before 1950, a vacuum of 10^{-6} torr, i.e., about 10^{-9} of atmospheric pressure, was considered very good. (Such a pressure exists at a height of 250 km above the earth.) However, even at this low pressure, a clean surface may be covered with a monomolecular gas layer in about one second. The time to perform an experiment on a clean surface at 10^{-6} torr is hence not very long!

Even before 1950, some extremely careful investigators had certainly succeeded in achieving pressures lower than 10^{-6} torr, but no systematic technique to guarantee "ultrahigh vacuum" existed. Around 1950, Alpert and co-workers at the Westinghouse Research Center succeeded in changing ultrahigh vacuum from an art to a science, and thereby opened a new era in surface science. With the use of modern ultrahigh vacuum techniques, the second problem mentioned above, sustaining a clean surface, can be solved.

So now, after preparing a good surface and keeping it clean, how do we study it? Many different tools exist, each with its own advantages and difficulties. One very powerful approach is the diffraction of low-energy electrons.* A distantly related approach is used by a group at the University of Illinois (Professors H. Frauenfelder, J. W. Burton and R. P. Godwin), sponsored by AFOSR. They use the Mössbauer effect to gain information concerning surface properties and surface processes. Before discussing this research, a short discussion of the Mössbauer effect in general may be appropriate.

To discuss the Mössbauer effect, we switch from surface physics to nuclear physics, and consider the emission of gamma rays by a nucleus. A gamma ray is a quantum of electromagnetic radiation emitted by a nucleus as a result of a quantum transition between two energy levels of the nucleus. Gamma-ray energies range from 10^4 to 10^7 electron volts, with correspondingly short wave lengths and high frequencies. Their

*For a more definitive discussion, See OAR Research Review, Dec. 1965, "Semiconductor Surface Studies by Low-Energy Electron Diffraction."

ability to penetrate matter is high. To determine gamma-ray energies, the most direct procedure is to determine the wave length, hence the frequency, by using a crystal as a diffraction grating. Other methods are to measure the energy of photoelectrons, Compton recoil electrons, electron-positron pairs or the absorption of gamma rays in matter. The phenomenon of recoilless gamma-ray emission and resonant gamma-ray absorption is called the Mössbauer effect. Resonance methods may be used to determine the spectrum of energies associated with gamma rays.

The energy of a gamma ray emitted by a nucleus is inherently very well defined. In some cases, the Q value, i.e., the ratio of the gamma-ray energy to the "uncertainty" in

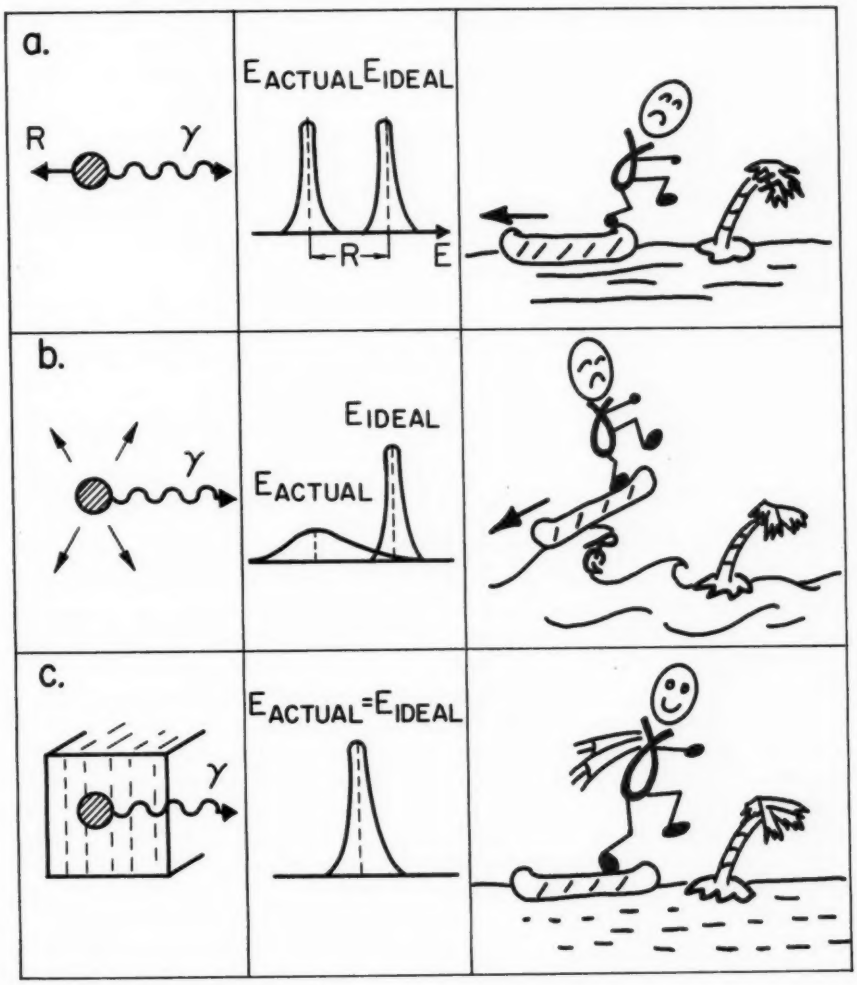


Fig. 1 *Recoilless emission of gamma rays*

1. a) *Emission by free nucleus at rest; the gamma ray loses the recoil energy R, the jumper falls short.*

1. b) *Thermal motion broadens the gamma-ray line; the jumper overshoots or undershoots.*

1. c) *The nucleus is "frozen" in the crystal; the jumper from the raft in the "frozen" sea lands accurately.*

its energy is of the order of 10^{13} or better. However, many effects conspire to wash out the intrinsically sharp gamma-ray line. The first of these effects is the recoil loss. (Fig. 1.a) A gamma ray not only carries away energy, but also momentum. In order to satisfy the laws of conservation of momentum and energy, the nucleus from which the gamma ray has been emitted recoils, and the recoil energy is "stolen" from the gamma ray. Recoil energy loss is familiar: consider the man jumping from a raft to a small island. In jumping, he pushes back the raft and loses the recoil energy. Unless he corrects for the energy loss, he will wind up in the water and not on the island!

Actually, the situation is even worse. (Fig. 1.b) The gamma ray is not emitted from a nucleus at rest, but the nucleus moves in the solid, liquid, or gas in which its atom is situated. The gamma-ray energy is therefore larger or smaller than the one expected, depending on the direction of motion. (This is the familiar Doppler effect.) Again, we can picture the situation in a familiar way: the man now tries to jump onto the little island in a violent sea. He may well be tossed over his goal, or fall way short, depending on the actual motion of the raft.

At this point the situation seems hopeless. However, at least for the man there is a way out: wait till the sea is frozen! In this case, he will no longer experience waves or recoil loss, and he can jump safely. Mössbauer found a similar way to "freeze in" nuclei. By selecting a proper solid, the situation becomes analogous to the frozen sea, and many gamma rays are emitted without experiencing recoil-energy loss or Doppler broadening. The existence of these unshifted, unbroadened, extremely sharp gamma-ray spectral lines is called the Mössbauer effect.

The quantum mechanical explanation of the recoilless emission of gamma rays is, in a first approximation, also simple. The solid in which the decaying nucleus sits is a quantum mechanical system, and therefore has discrete energy levels. Consider the solid to be described by the Einstein model; the separation of the energy levels is then E_E, the Einstein energy. For the discussion of many physical effects in solids, the more sophisticated Debye model is required. The Einstein model is adequate, however, for a qualitative discussion of the Mössbauer effect. If the recoil energy of the nucleus is much smaller than E_E, then the solid cannot accept this energy, and the gamma ray is emitted with full energy. A large Einstein energy corresponds to a tightly "frozen" nucleus, i.e., one which cannot easily move. In fact, the Einstein energy can be expressed in terms of an atom's mean square displacement from its expected position.

The importance of the Mössbauer effect lies in the sharpness of the emitted line. The sharpness is measured by absorbing the gamma ray resonantly by nuclei of the same type. Only if the gamma ray was emitted without energy loss will resonance take place. By moving the absorber relative to the source, the actual spectrum of the source can be observed. Hundreds of solid-state experiments have already been performed using the Mössbauer effect, and the chemical compounds studied so far also number in the hundreds.

The application of the Mössbauer effect to surface studies is, in principle, straightforward: the radioactive atoms are deposited on the surface to be studied. The Mössbauer spectrum is observed as a function of temperature and angle of gamma-ray emission with the surface. The spectrum then should give information on the binding to the surface, on the effective Einstein (or Debye) energies at the surface, and on the magnetic and electric fields. While the advantages of surface Mössbauer experiments are easy to enumerate, the difficulties are also easy to point out, but hard to overcome. All experiments must be performed in ultrahigh vacuum; the surface must be well cleaned and the radioactive material must be deposited in less than a monolayer. Finally, the temperature of the surface should in most cases be held well below room temperature; otherwise, the tracer atoms may rapidly diffuse to a crack or surface imperfection, and hence falsify the results.

The experiment carried out by Professor Frauenfelder and his group at the University

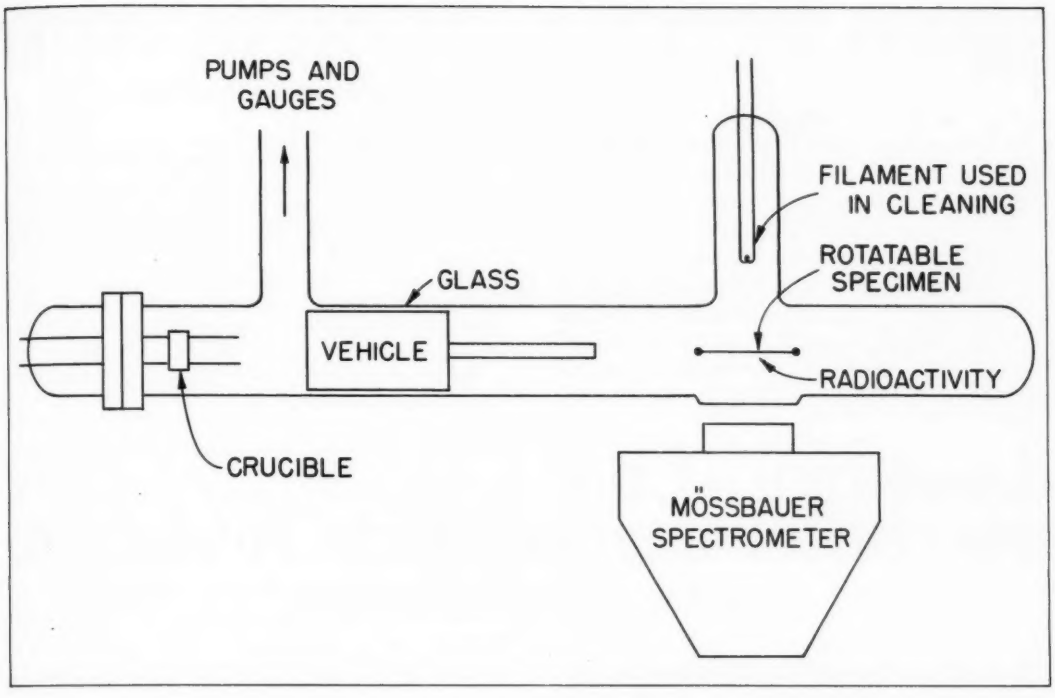


Fig. 2 Schematic of Apparatus for Surface Studies by Means of the Mössbauer Effect.

of Illinois was performed in an ultrahigh-vacuum system which could be evacuated to 10^{-10} torr. (Fig. 2) The pumping equipment consisted of molecular sieve starting or roughing pumps, ionization pumps for continuous operation, and a titanium sublimation pump for handling pressure bursts occurring during evaporations. A double evaporation process was used to obtain a deposition of about one-tenth monolayer of "clean" Co^{57} Mössbauer nuclei on the final target. The initial evaporation assembly was a tungsten crucible mounted on a removable vacuum flange that allowed insertion of the radioactive source. After sample insertion and evacuation of the system, the transfer vehicle was placed over the crucible containing the Co^{57}. All parts of the apparatus directly involved in the measurements were cleaned by heating. The crucible was then raised to a very high temperature to evaporate the radioactivity onto the transfer vehicle. The vehicle was then moved by means of a magnet into position in front of the tungsten final target for heating to deposit the radioactivity onto the final target, which had been thermally cleaned by electron bombardment for many hours.

Finally, after thus preparing the final source, the Mössbauer spectrum was observed as a function of target temperature and emission angle. The spectra obtained indicate that the atoms are indeed on the tungsten surface and not in the bulk of the target, and that an electric-field gradient of about minus 2 times 10^{16} volts per square centimeter exists perpendicular to the surface. The temperature dependence of the Mössbauer effect yields Debye temperatures (Debye temperatures are proportional to the Debye energies) of about 260 degrees Kelvin parallel to the surface and 350 degrees Kelvin perpendicular to the surface, while bulk measurements yield a Debye temperature of about 410 degrees Kelvin. These results indicate that the surface Mössbauer atoms are freer to move than the bulk atoms, and that

the binding of the atoms on the surface is stronger perpendicular than parallel to the surface.

The Mossbauer effect with its ability to microscopically sense electric and magnetic fields, electronic-charge densities and details of lattice bonds appears to be a tool which should be further exploited in surface studies. Despite the difficulties of the techniques involved in surface Mossbauer experiments, it is hoped that systematic studies of various types of crystal surfaces will be made, and that the lack of meaningful quantitative experimental data will give way to more knowledge and better understanding of phenomena occurring on the surfaces of solids. ★

SELECTED BIBLIOGRAPHY

Burton, J. W., H. Frauenfelder and R. P. Godwin, "Surface Studies Using the Mössbauer Effect," Advisory Panel on Mössbauer Spectroscopy of the International Atomic Energy Agency, Vienna, Austria, 26-30 April 1965. (Proceedings to be published)

Frauenfelder, H., The Mössbauer Effect, W. A. Benjamin, Inc., New York, 1963.

Maradudin, A. A., "Lattice Dynamical Aspects of the Resonance Absorption of Gamma Rays by Nuclei Bound in a Crystal," Rev. Mod. Phys., 36, 417, 1964.

Wallis, R. F., "Surface Effects on Lattice Vibrations," Surface Science, 2, 146, 1964.

simulation of the solar wind-magnetic field interface

SPACE PHYSICS LABORATORY, AFCRL

When the solar wind reaches the earth's magnetic field, it compresses the field on the side toward the sun, and stretches it out like a tail on the side away from the sun. The magnetic field acts as a barrier to the electrons and ions of the solar wind, preventing their direct entry into the earth's atmosphere. As a result, there are sharp discontinuities in both the field and the solar plasma wind. The discontinuity on the side toward the sun has all the characteristics of a shock front, or "bow shock." We know quite a bit about shock fronts--but this is a shock front of a special type. It is a "collisionless shock," and this introduces some difficulties into the development of a theory to describe the solar wind-magnetopause interaction.

Scientists have only recently appreciated the dynamic processes at the solar wind-magnetic field interface, and the relationships of these processes to the aurora, to geomagnetic fluctuations and, to some extent, to the ionosphere itself. The mechanism of the collisionless shock that takes place at the solar wind-magnetic field interface is not well understood.

AFCRL scientists have built a plasma accelerator that can produce a high-velocity plasma that roughly simulates the solar wind. Since April 1964, Dr. Allen Rubin of AFCRL has conducted solar-wind-simulation experiments with this accelerator. These experiments have shed light on what happens when the solar wind interacts with the earth's magnetosphere.

Particle density in the plasma is about 10^{14} per cubic cm, and particle velocity about 5×10^{6} cm per second. In the experiments conducted with the device, a stream of this plasma is directed into the dipole field of a pulsed coil that produces a maximum field strength of 5,800 gauss. The result of this interaction is photographed with a high-speed camera.

In the experiments so far, a shock standing off from the coil has been clearly observed. This shock has a well-defined structure, including the parabolic shape predicted by theory. Measurements of perturbations in the dipole field caused by the plasma will be made, and the base pressure of the vacuum system will be improved to prevent stray gas molecules from interfacing with the formation of the shock. ★

THEORY AND APPLICATION OF DIGITAL FILTERING

CAPT JOHN JONES, JR.
Directorate of Mathematical Sciences, AFOSR

Methods for processing signals that are functions of a continuous time variable were developed long before the advent of high-speed digital computers. Due to the widespread use of digital computers, there arose the need for a filtering theory of digital signals.

The problem of relating the theory of filtering digital signals and continuous-(analog)-type signals was recently investigated by Dr. Kenneth Steiglitz* while at New York University. This problem is part of the research in sampled data theory and digital filtering supported by the Applied Mathematics Division, AFOSR, being carried out at New York University under the direction of Professors John Ragazzini and Sheldon Chang.**

The research results appear in the technical report, AFOSR 64-1664. The filtering theory for both continuous-time and discrete-time signals is formulated in a Hilbert space with the notion of a stable filter being defined as a bounded linear operator on a Hilbert space. An isomorphism (pairing) between the analog and digital spaces allowed the transfer of concepts from one domain to the other. In this setting, it was found that a z-transform (operator) can be defined with much the same generality as the well-known Fourier transform which led to the definition of stable filters that can be used in both the analog and digital cases. It was seen that any such filter, whether time-varying or not, could be represented by an infinite matrix of numbers. In particular, in the time-invariant case, the digital and analog theories are essentially identical. Thus, many common optimum-filtering problems can be solved simultaneously for analog and digital signals, both in the deterministic and in the random cases.

Other results include data-reduction filters and their interpretation in terms of frequency response, and the equivalence of the approximation problem for time-invariant digital and analog filtering cases. These ideas were applied to the problem of measuring power-spectral density from digital information.

This research has already been found to be of direct value to the Air Force. The results obtained by the Rome Air Development Center in analyzing experimental data for the Echo II satellite have been improved by the application of the theories discussed in the AF-AFOSR 64-1664 technical report. ★

* *At present Assistant Professor of Electrical Engineering at Princeton University.*

** *At present Professor of Electrical Engineering, State University of New York, Stony Brook.*

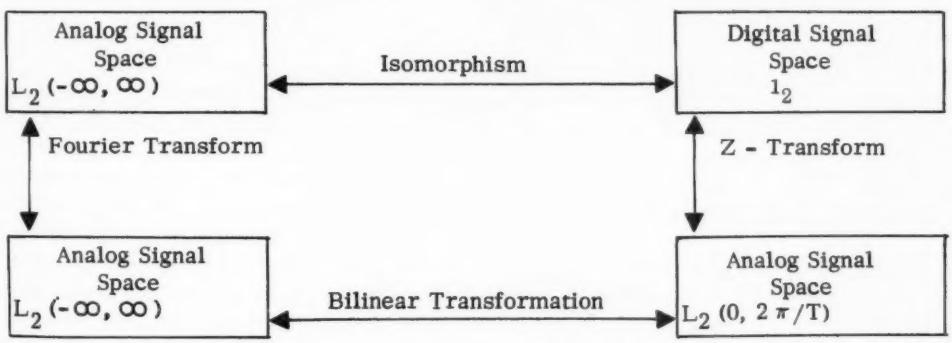
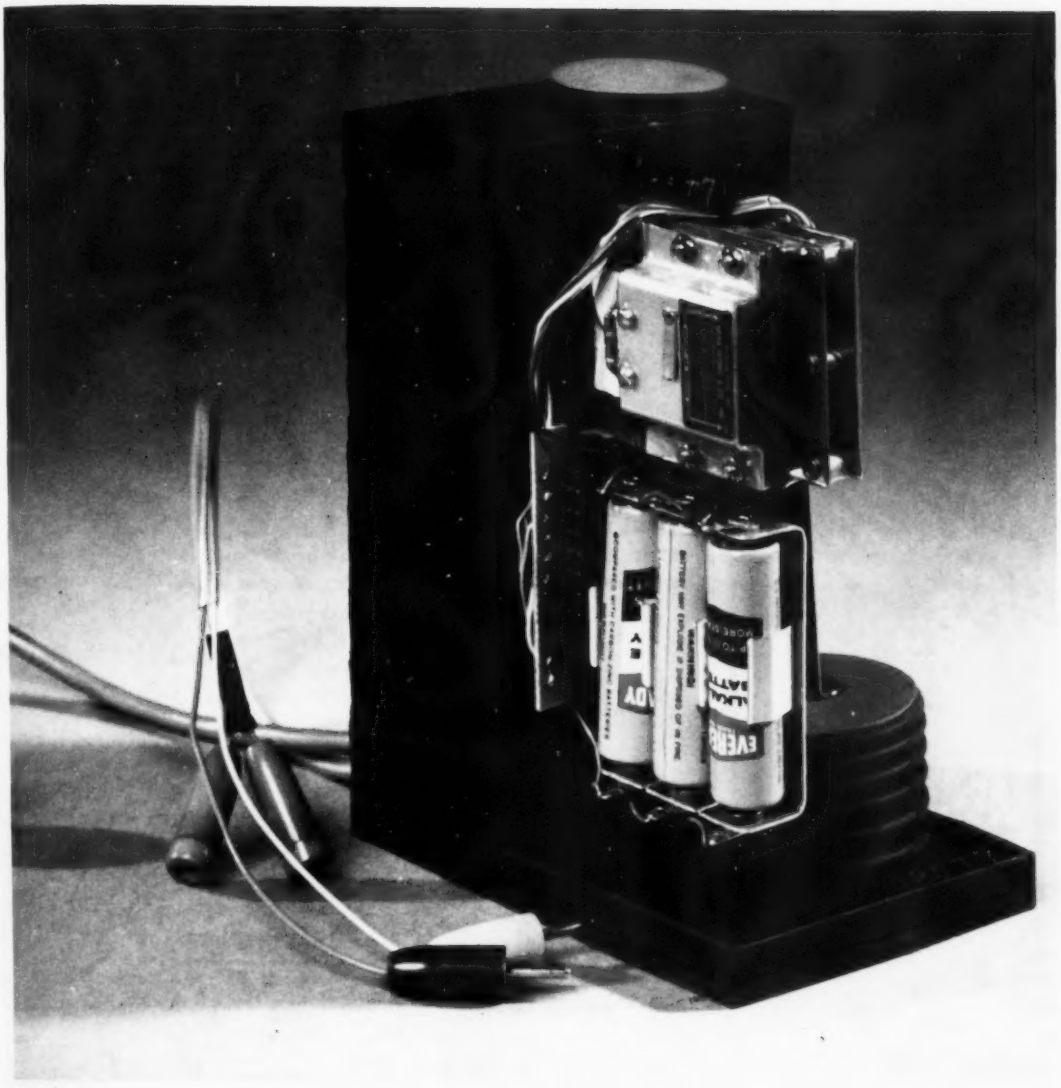


Fig. 1. A Schematic Representation of the Mapping and its Relations to the Various Signal Spaces.

AFCRL INSTRUMENTATION AND APPLICATION

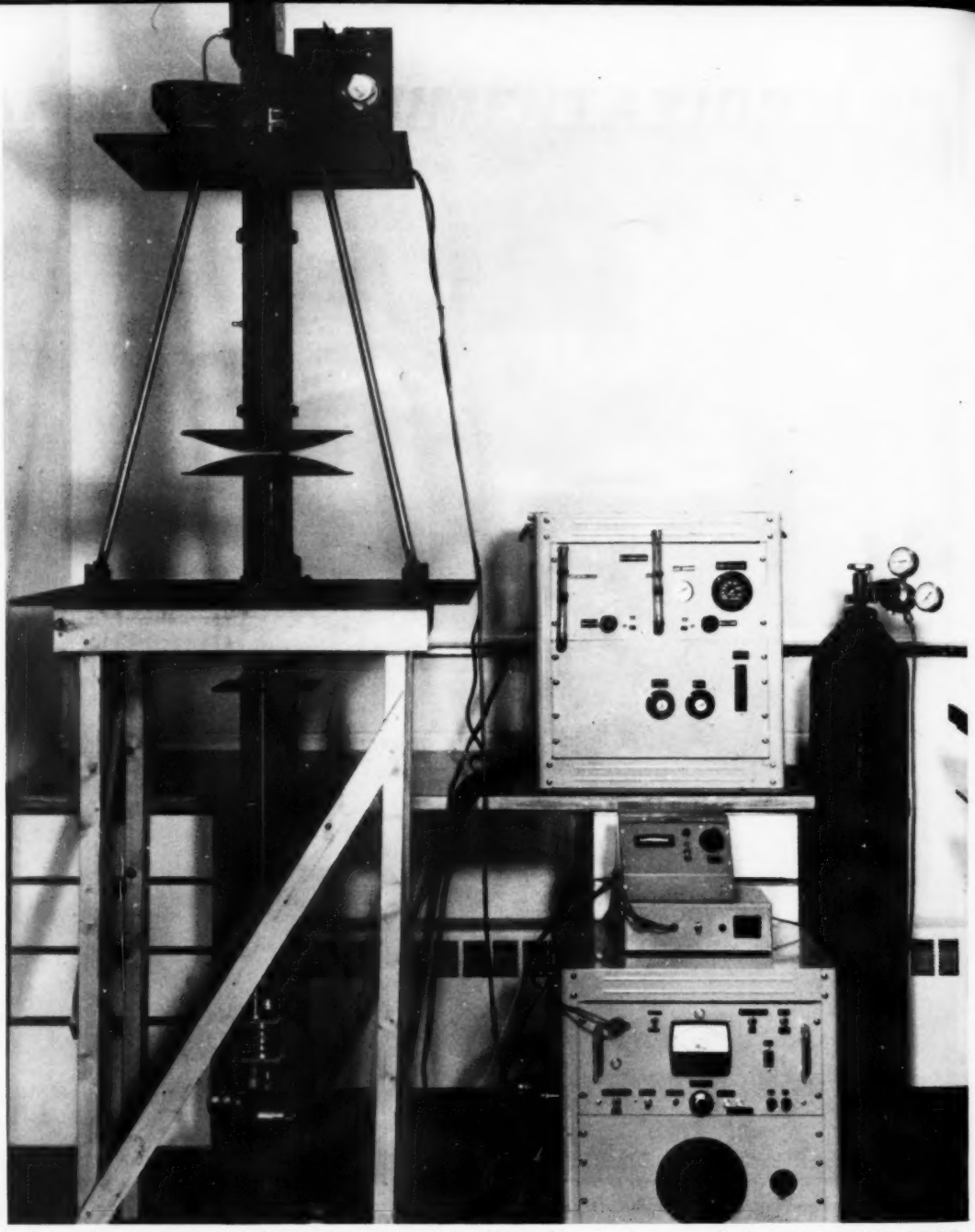
U.S. Playas. During the past several years, AFCRL and its contractors have examined some 60 dry-lake beds (playas) in the southern part of the U.S. Playas are the flattest of all land forms, often sloping only one foot per mile or less. In the desert areas of North America there are several hundred playas over three square miles in area. They are found all over the world, usually in arid or desert areas.

Of particular interest are the weight-bearing properties of these lake beds, a property being measured here. Such lake beds can serve as natural landing areas for operational aircraft and as sites for large antenna arrays. (U.S. playas were described in detail in the September 1965 Review, in "Comprehensive Survey of Playas Published.")



Atmospheric Circulations Over the North American Continent. The small, inexpensive, and expendable ozonesonde units of the type shown above are extremely sensitive to changes in ozone concentrations. Hundreds have been carried to extreme altitudes by conventional meteorological balloons, during AFCRL's extensive two-year program of ozone observations over the North American continent. Ozone reacts strongly with certain chemicals, producing chemiluminescence. The amount of chemiluminescence produced is a measure of ozone concentrations.

Ozone concentrations in the stratosphere and upper troposphere have proved to be the best--and, to some extent the only--means for tracing large-scale atmospheric motion at altitudes between 8 and 30 km. Certain patterns of ozone concentrations and temperatures may also provide clues to the existence of clear air turbulence. (The AFCRL program for using ozone as a natural tracer of atmospheric circulations was reported on in the September 1965 Review, in "Atmospheric Circulations Over the North American Continent.")



Laser Photography and Atmospheric Particles. Shown here is the laser disdrometer used by AFCRL in fog research at Otis AFB, Mass. This instrument was developed by Bernard A. Silverman of AFCRL and Technical Operations Research people (Burlington, Mass.) for measuring the size distribution of particles suspended in the atmosphere--raindrops, aerosols, ice crystals, snowflakes and cloud and fog droplets. The fog droplets pass through the opening at the center of the system. The recording camera is at the top, and the laser gun is at the bottom of the system.

This unique instrument gives the researcher his first clear view of the distribution of these particles in situ, undisturbed by the measuring or detecting processes. (The laser disdrometer was reported on in detail in the September 1965 issue of the Review, in "Laser Photography and Atmospheric Particles.")

vibration of electronic and human components treated statistically

ALFRED CRANCER, JR.
Directorate of Mathematical Sciences, AFOSR

Numerous quantities of interest in missile and spacecraft performance often can be represented as normal stochastic processes, stationary for a reasonable length of time. Examples of such quantities are the vibration of electronic components in missiles and spacecraft and the vibration of the brain and other vital organs in humans during space flight.

Frequently, interest is focused on the distribution function of these quantities at maximum tolerance values. When maximums are exceeded, electronic components short out, space pilots black out, and missions fail.

Recently completed research by Dr. Ross Leadbetter, Research Triangle Institute, under the sponsorship of the Air Force Office of Scientific Research, is addressed to determining the distribution of such functions. Two natural definitions for the distribution function of the height of an arbitrary local maximum of a stationary process are given and are shown to be equivalent. It is further shown that the distribution function as defined is an ergodic process. Finally, explicit results are obtained for a stationary normal process.

In this instance, Dr. Leadbetter's prior contact with statistical problems in the Department of Defense suggested a profitable line of research concerning local maxima of stationary processes. These ideas formed the nucleus of the completed research described above.

This research will be published late this year in the Proceedings of the Cambridge Philosophical Society. Advance copies may be obtained by writing to the Mathematics Division, Air Force Office of Scientific Research. ★

HIGH-RESOLUTION SPECTROGRAPH

ADOLPH S. JURSA, Upper Atmosphere Physics Laboratory, AFCRL

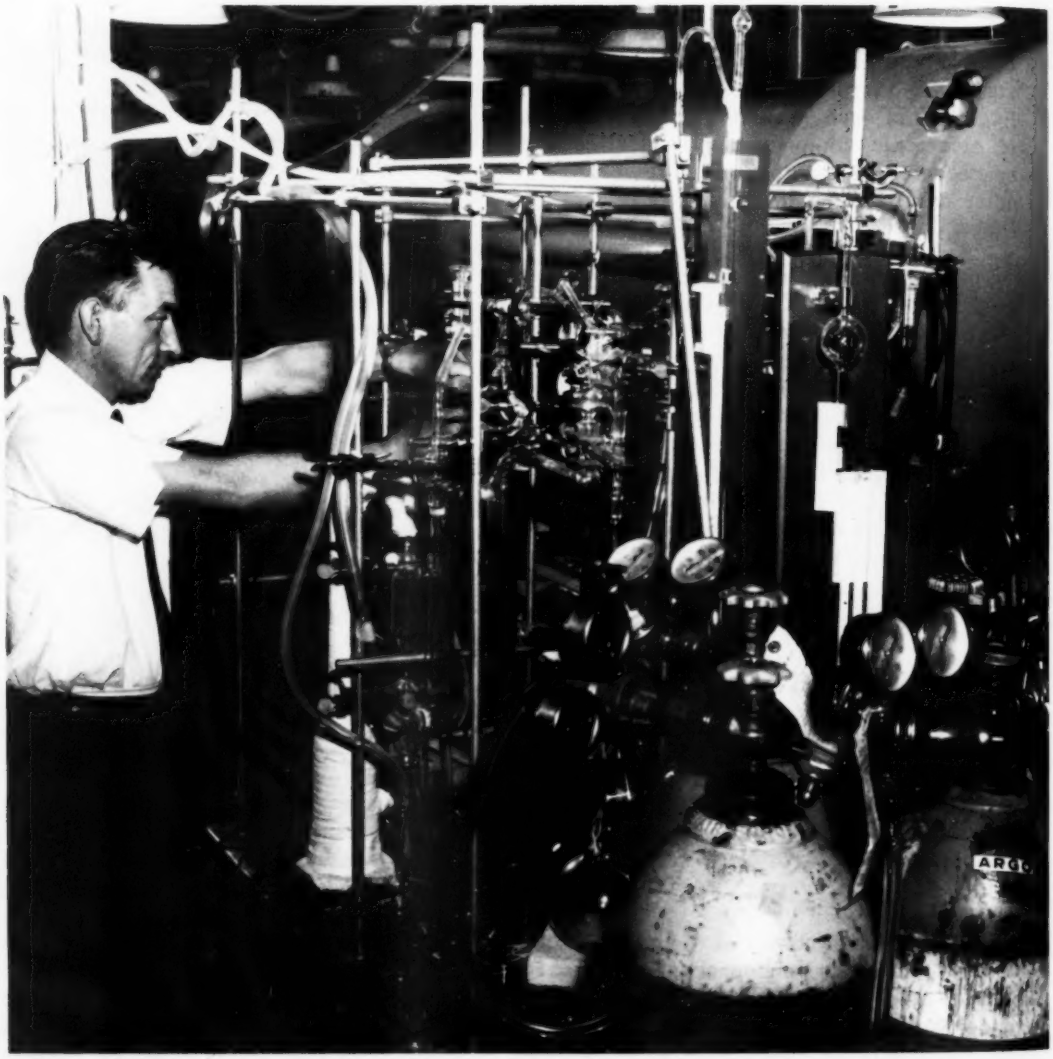
A 6.6-meter normal-incidence vacuum spectrograph, providing the highest spectral resolution presently obtainable, is now being calibrated and tested at AFCRL and will soon be placed in operation. The vacuum spectrograph will be used to observe the spectral characteristics of the kind of gases found in the upper atmosphere.

The new spectrograph will operate at optical frequencies between 300 angstroms in the extreme ultraviolet and 12,000 angstroms in the infrared. The high resolution of the instrument will permit scientists to observe rotational energies heretofore unobservable because of limitations of existing instruments. Spectral lines resulting from absorption and emission of energy by rotating molecules at certain optical wave lengths are used to interpret the structure of various gas elements and to understand their interaction with radiation at given wave lengths. The new equipment will make interpretation easier by providing the spectroscopist with sharp spectral detail.

The addition of the new spectrograph to facilities already in use makes AFCRL one of the most completely equipped centers in the world for ultraviolet spectrographic research. Other AFCRL spectrographic equipments consist of a one-meter and a three-meter normal-incidence spectrograph, a one- and two-meter monochromator, and a

6.8-meter grazing-incidence spectrograph.

Spectrograph size is measured in terms of the radius of curvature of the grating--the basic spectrograph component. The spectrograph is housed in a vacuum tank 25 feet long and 3 feet in diameter. It rests on a 15-ton concrete slab. This concrete mount, in turn, rests on a system of air cushions. This suspension system provides a resonance frequency of less than 1 cps. Stability is required for the long-term photographic exposure of spectral images. The system is thus relatively free from blurring, which can be caused by vibrations from the laboratory building in which the spectrograph is installed. ★



High-Resolution Spectrograph. Dr. Peter K. Carroll, physicist of the AFCRL Upper Atmosphere Physics Laboratory, is shown making adjustments on the gas-handling system used to produce a vacuum ultraviolet light source. In the background is seen AFCRL's recently installed 6.6-meter normal-incidence spectrograph. Electrical discharges through highly purified gases such as helium, argon, krypton, and xenon are valuable sources of continuing radiation in the vacuum ultraviolet.

TO OUR READERS

Request for further information should be directed to the individual or laboratory of origin (except for those from Latin America).

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